Measurement and calculation of leakage neutron spectrum in light water

By J. Lolich and M. Abbate

Centro Atómico Bariloche, Comisión Nacional de Energía Atómica, 8400 San Carlos de Bariloche, Argentina

Abstract

Leakage neutron spectrum measurement has been made in pure light water using standard time-of-flight techniques. The measurement was compared to calculations performed with the ENDF/GASKET scattering model in conjunction with a modified version of the DTF-IV code in S_8, P_0 and P_1 approximations. The P_0 approximation proved to be satisfactory, for the spectra studied, being the largest discrepancy between theory and measurement of 8 %.

Zusammenfassung

Messung und Berechnung des Ausfluß-Neutronenspektrums in leichtem Wasser

Es wurde eine Messung des Neutronenspektrums in einer Grenzfläche zwischen leichtem Wasser und Vakuum mit der Standard-Flugzeittechnik durchgeführt. Die Messung wurde mit Berechnungen verglichen, die mit dem Streumodell ENDF/GASKET zusammen mit einer modifizierten Version des DTF IV in der S_8, P_0 und P_1-Näherung durchgeführt wurden. Dabei zeigte sich, daß die P_0-Näherung für die untersuchten Spektren zufriedenstellend war. Die größte Abweichung zwischen Theorie und Messung waren 8 %.

INIS DESCRIPTORS

NEUTRON SPECTRA	SPHERICAL HARMONICS METHOD
NEUTRON LEAKAGE	ACCURACY
WATER	NUMERICAL SOLUTION
TIME-OF-FLIGHT METHOD	COMPUTER CALCULATIONS
COMPARATIVE EVALUATIONS	D CODES

Introduction

In nonmultiplying media, the neutron spectra distorsions due to strong flux gradients are very large and hard to calculate. The investigation in such a medium is designed to test the transport properties of the assumed scattering kernel. This factor is, of course, important in the description of the neutron behavior at absorption discontinuities in reactors.

In a previous paper [1], results for the neutron thermalization in pure and borated H_2O in a quasi-infinite-medium were reported. The experimental work was performed in such a way that there was no spatial variation of the neutron flux at the point of measurement for all energies. The comparison with theoretical transport predictions were given, with satisfactory agreement. The obvious conclusion to be drawn from the previous "infinite medium" work was that the ENDF/GASKET [2], scattering kernel in conjunction with a modified version of the DTP-IV code [3], were good enough to describe the observed neutron spectra.

In this paper, we present measurement and calculation of the leakage-neutron spectrum from pure H_2O. It is an extension of the previous spectral work to include studies where flux gradients become important, which is the case of the angular flux spectrum in a plane boundary between moderator and vacuum and it is aimed to verify and extend the experimental method.

This research is part of a program of the Argentine "Comisión Nacional de Energía Atómica" (CNEA) to evaluate the various models, codes, and data sets used to calculate the spectra in water moderated lattices and to analyze the sensitivity of cell parameters to the scattering law.

Description of the experiment

The experiment consisted basically of measuring the leakage neutron spectra in pure water at 23° C, using the time-of-flight technique. The Linac facility of the Centro Atómico Bariloche was used for this experiment. This facility is described in [4].

The experimental geometry, illustrated in Fig. 1, comprised a cubical tank, 30 cm on a side, lined with cadmium sheet and shielded with a boron mixture. The neutron beam was extracted from the aluminium tank wall (0.05 cm thick) via a 25 mm dia. hole through the neutron shielding. The neutron background was obtained by placing a ^{10}B plug in the shielding hole. A 17 m flight path was used. The neutrons were detected by means of a ^6Li glass scintillator and the neutron beam was monitored with two small ^{235}U fission detectors placed in different positions inside the vessel. Running time for the experiment was chosen to ensure good statistical accuracy. The mean temperature of H_2O for all the measurements was 23° C, it was monitored with an iron-constantan thermocouple.

The mean emission time at low energies was evaluated from die-away experiments, for the intermediate neutron energies was calculated with the CAGE [5] program and for the upper range of energies was obtained from the slowing down time. A more detailed description is given in Ref. [1].

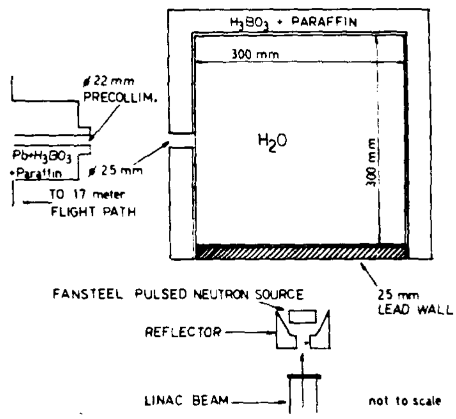

Fig. 1: Experimental set-up used to measured neutron leakage spectrum in H_2O

Careful static measurements of the thermal and epithermal flux distributions were done using indium foils in conjunction with the cadmium difference method.

Extensive foil activation measurements were done in the source (axial) direction, since the exponential spatial decay of the source is the main contributor to the correction that transforms the three-dimensional medium into fictitious one-dimensional medium, namely the buckling.

The intercalibration of the activation detectors was carried out by irradiating them in a neutron flux while being mounted on a rotating cylinder. From the distribution close to the tank wall from which the neutron spectrum was extracted, the inverse relaxation constant γ was derived to get the local buckling. From the transverse distribution, the spatial form of the source was obtained.

The reduction and treatment of data applied to the experimental results were the same described in Ref. [1].

Calculation method

The scattering kernel based on the ENDF/GASKET model [2], for bound hydrogen in H_2O and assuming free translation for the oxygen was generated by means of the GASKET code [6]. The cross sections group P_0 and P_1, for 30 energy groups were calculated using these scattering kernel with the codes NYR190 [7] and NYR081 [8]. Using as data the measured transverse

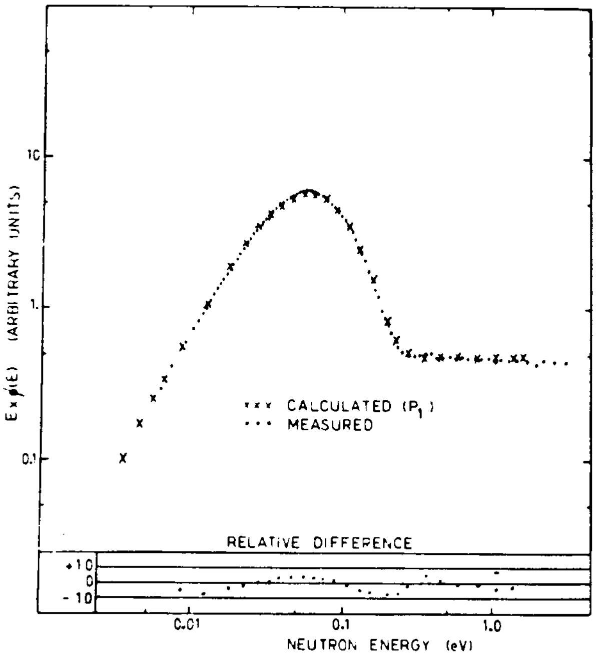

Fig. 2: Neutron leakage spectrum measured in H_2O compared to calculation using P_1 approximation

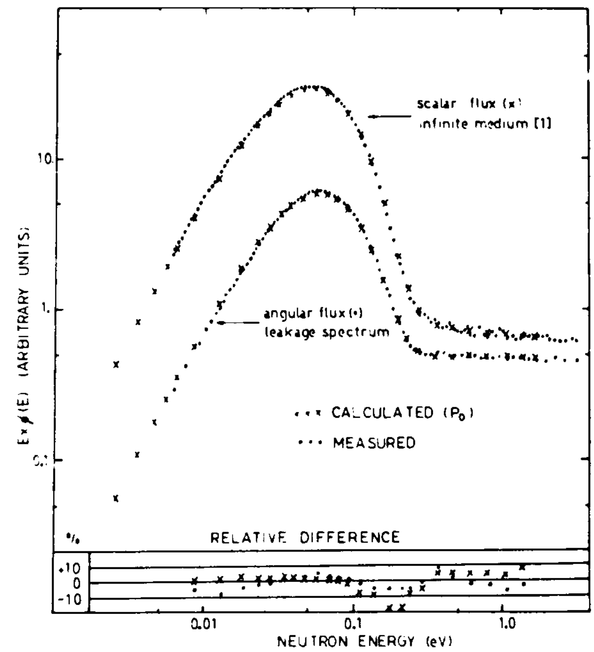

Fig. 3: Neutron spectra measured in H_2O compared to calculations using P_0 approximation

spatial distribution of epithermal neutrons, a one-dimensional distributed source was calculated with the NYR232 [9] code.

The transport theory calculation to obtain the angular neutron spectra was done with the NYR230 [3] code (a modified version of the one-dimensional DTF-IV code), in 15 spatial intervals, using the 30 groups cross sections, S_8 approximation and the computed distributed source. The flight path axis was the direction accounted for the one-dimensional calculations. Both P_0 and P_1 scattering kernel approximations were considered.

A comparison of the transport theory calculation in P_1 approximation with the measured spectrum is shown in Fig. 2. The results were normalized to equal area between 0.0065 eV and 1.66 eV.

Discussion of results

As shown in Fig. 2, the agreement between theory and experiment is satisfactory. The transport calculation agrees with the measured spectrum within + 5 % to − 8 %.

In order to compare the present deviations with those obtained for the spectra in quasi-infinite medium [1], a new intercomparison between theory and experiment was carried out for the later, normalizing them to equal area. The results are shown in Fig. 3 together with the present experimental and calculated results (in P_0 approximation). A systematic deviation between theory and experiment is observed in the energy range around 0.2 eV, which cannot be attributed to statistical uncertainties nor to resolution errors.

The smaller discrepancies of the present work could be attributed to the lack of a reentrant hole tube in the geometry, to the improvement done in the collimator shielding and to the carefully static measurements done in the present work.

Neglecting the P_1 scattering makes little difference (less than 1 %), in the surface spectrum, then it could be concluded that the P_0 approximation is suitable to describe the neutron leakage spectrum in small H_2O assemblies.

Conclusions

The good agreement between theory and experiment, supports the view that the P_0 scattering by H_2O is adequately described by the ENDF/GASKET model and that a transport theory calculation in P_0 approximation is very suitable for small H_2O assemblies in which discontinuities are present.

The results, then, are important because they indicate a degree of accuracy in the present scattering description of H_2O that is adequated for many types of reactor-design calculations. Its adequacy for calculation of neutron spectra in large flux gradients, such as at control-rod surfaces or at fuel-cell edges, remains to be determined.

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